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Fortsetzung 3. Umschlagseite

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The adrenal weight changes of a tropical fruit bat, Rousettus aegyptiacus E. Geoffroy

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Receipt of Ms. 20. 12. 1979

Abstract

Adrenals were collected from a colony of fruit bats (*Rousettus aegyptiacus*) for over a year. The relative adrenal weights are highest in the foetuses and they follow roughly the same trend as the absolute weights in the postnatal life. The adrenal weights increase with age and the adult adrenal weight is attained before the bats are sexually mature. The adrenal weights show a disproportionately heavier left than right gland especially during pregnancy. The gland weights exhibit sex differences with the breeding males having a higher average than their coevals. There is an increase of adrenal weights with the advance of pregnancy and this declines suddenly at parturition. The greater proportion of adrenal weight increase during pregnancy is contributed by the left gland. The effect of either wet or dry seasons on the adrenal weights is not statistically significant and the little change there appears to be associated with breeding.

Introduction

The size of the adrenal cortex estimated by adrenal weight has been used as an indirect measure of social stress in wild mammalian populations (Christian 1962). Knowledge of the weights of the adrenal glands is often used in estimating functional status of animals particularly the small mammals such as rodents. Preliminary to an assessment of the effect of population density on adrenal size, is an understanding of seasonal changes in adrenal weight in relation to body weight; and of the physiological factors that determine adrenal weight. It is apparent that many factors, both internal and external influence adrenal size. Sex, age, reproductive status, season, breeding, population density, disease and availability of food are factors that may affect the adrenal weight changes.

In proportion to the body weight, the adrenal weight varies from strain to strain and from species to species. A weight change in the adrenal glands of one species of mammal may be related to a factor for which adrenals of another species show no apparent response.

A vast amount of information has been collected about the adrenal gland weights of mammals especially of man, dog, laboratory rat, mouse, rabbit, guinea-pig, and hamster (Jones 1957). The adrenal glands of bats have not yet been studied in detail and thus the data on these aspects are scanty. And even less is known on the behaviour of this endocrine tissue in tropical mammals. This study was initiated to gather information on the variation of adrenal weights with respect to sex, age, breeding condition, wet and dry seasons. *Rousettus aegyptiacus* was selected for this investigation because of its sustained high numbers of individuals in their caves throughout the year.

Unlike *R. aegyptiacus* in Egypt (Flower 1932), these bats in Uganda breed twice a year (Mutere 1968; Baranga 1978). The gestation period is about four months. Lactation lasts for about four weeks and mating seems to take place during this period. With this kind of schedule, these bats have very little time for resting between parturition and the next pregnancy.

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Materials and methods

A collection of 700 individuals of *Rousettus aegyptiacus* was made from caves on the shores of Lake Victoria, Uganda. This area, elevated between 1066 and 1219 m above sea level, receives 1250 to 1500 mm of rain annually and is generally covered by Medium Altitude Moist Evergreen forest.

Sampling was once every month for more than 12 months. The animals were housed in the Zoology Animal Yard bat cages for one night where they fed ad lib. on ripe pawpaws, bananas and slices of pineapple. The bats were chloroformed, weighed to the nearest 0.1 g. on a Sartorius toploader before other measurements, inspections and dissections were made. Records included body weight, forearm length, sex, state of maturity, condition of breeding, external and internal parasites.

Care was taken to place the collected glands in the fixative within three minutes of death. The adrenals were cleaned of fat on the day following dissection and rolled twice on Whatman filter paper before weighing to the nearest 0.01 mg on a Metler analytical balance.

For both sexes the demarcation between mature and immature *R. aegyptiacus* in the area, is 90 g body weight and 90 mm forearm length; these being the minimum dimensions of a mature bat (Mutere 1968). In addition to the above dimensions, breeding females have prominent teats, and their uteri are richly supplied with blood vessels and/or distended. The fruit bats reproduce twice a year in the locality with parturition peaks in February/March and September/October. Since there does not seem to be a resting period between lactation and pregnancy, all the female bats which have already had young ones or are pregnant are considered breeding. Breeding males are mature bats with very big testes and seminal vesicles.

Non-breeding males and females refer to mature bats with very tiny testes and seminal vesicles; and thin walled, tiny, undistended uteri devoid of a rich blood supply respectively. Immature males and females are bats which have not yet attained the 90 g body weight and 90 mm forearm length.

The age of foetuses refers to the approximate age of pregnancy. Pregnant bats show clear embryo presence in the uteri as early as the first half of the first month of pregnancy. For purposes of this study four main stages of reproductive condition were considered:
Early pregnancy: uterus enlarged with about $^1/_2$ to $1^1/_2$ months old embryo,
Mid-pregnancy: with about 2 to $2^1/_2$ months old embryo,
Late pregnancy: with about 3 to $3^1/_2$ (and close to parturition) months old embryo.

Lactation here refers to a period between parturition and weaning during which time the young clings to its mother's abdomen.

Results

Weights of right and left adrenals

The contribution to total adrenal weight of right and left glands is not equal. In general, the left adrenal is slightly but persistently heavier than the right one, and in many individuals the difference is as small as 0.1 mg, while in others it is as large as 4.0 mg.

There are many individual exceptions but there is never any age group with a higher mean right than a mean left adrenal weight. The condition of disproportionate adrenal weight favouring the left gland is common to all age groups and sexual states of the bats examined.

When percentage differences were calculated for the three age groups of both sexes, it was found (tab. 1) that there are different age biases in the two sexes. Among the male bats, the

Table 1

Disproportionate weight percentages in favour of heavier left than right adrenals

Age groups	Males	Sample size	Females	Sample size
Foetal	0	(9)	0	(9)
Immature	4.4	(36)	2.5	(36)
Non-breeding	10.5	(36)	4.5	(19)
Breeding	8.1	(36)	7.1	(36)

The percentages given here are calculated from the differences between the mean left and mean right adrenal weights. Sample size refers to pairs of adrenal used in calculating the mean weights.

highest percentage of adrenal weight difference (10.5%) was recorded in the non-breeders while in the females the breeders have the highest mean difference (7.1%). During late pregnancy, the left mean adrenal weight averages about 10% heavier than the right one.

In dealing with pregnant bats, attempts were made to correlate the disproportionate adrenal weight with the pregnant uterine horn, but no meaningful bias was found in that direction. When numerical comparisons are made on the number of individuals with heavier left than right adrenals, the lowest (11%) is recorded in the foetal group and the highest (91%) in the pregnant females. Thus the additional adrenocortical tissue required by the breeding females, is disproportionately distributed in favour of the left adrenal. As can be seen in table 1, disproportionate weight percentages vary with age groups and sex but the constant feature is that the majority of non-foetal bats have heavier left than right adrenals.

Adrenal weight changes with sex

It is clear from table 2 that no significant difference exists between the male and female mean adrenal weights. The largest difference in absolute adrenal weights is found in the breeding specimens in favour of the males. However, even this is not statistically significant.

Table 2

Sex differences in adrenal weights

Age group	Sex	Adrenal weight range (mg)	Mean absolute adrenal weight (mg) ± SE	mean relative adrenal weight (mg) ± SE	Sample size
Immature	Males	1.8–18.6(104)	8.7 ± 0.709	0.169 ± 0.006	36
	Females	1.4–17.9(60)	8.2 ± 0.684	0.166 ± 0.007	36
Non-breeding	Males	10.1–32.6(81)	18.1 ± 0.787	0.167 ± 0.006	36
	Females	11.4–33.8(31)	18.3 ± 1.250	1.177 + 0.110	19
Breeding	Males	13.6–41.7(164)	23.2 ± 0.822	0.172 ± 0.006	36
	Females	4.8–42.0(217)	20.5 ± 1.049	0.169 ± 0.007	36

Wherever it occurs, sample size means the number of bats (pairs of adrenals) used in calculating the means and the standard error (SE). – The sample size for the adrenal weight range is given in parentheses after the figures.

Age related changes

The adrenal weights increase with age from foetal life until the late juvenile stage. As can be seen in fig. 1, plotting adrenal weights against estimated age, shows a short term shallow depression at the time of birth (zero age), indicating a temporary lag in the adrenal growth rate. The highest growth rate is observed in the first four months of postnatal life and thereafter the graph zigzags before flattening off, implying the interference of other factors as the adrenals mature.

Forearm length is one of the criteria used to determine the rate of growth and the stage of maturity in bats. Increase in forearm length is much faster than adrenal gland growth. This is made clear by plotting forearm length against paired adrenal weights (fig. 2). The first part of this curve is marked by an initial rapid increase of the forearm length as compared to the rate of increase in adrenal weights.

The second phase is characterized by a faster rate of adrenal weight increase than forearm length. During this period, the former doubles its initial weight while the latter increases

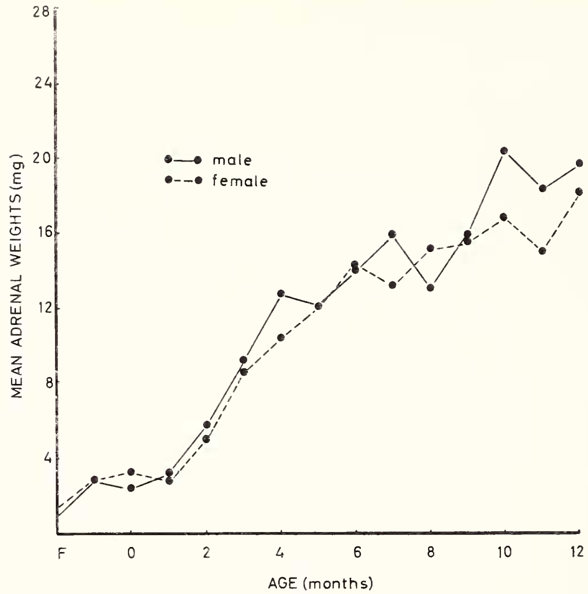


Fig. 1. The changes of mean absolute adrenal weights with estimated age. F = foetus; O = born on the day of dissection

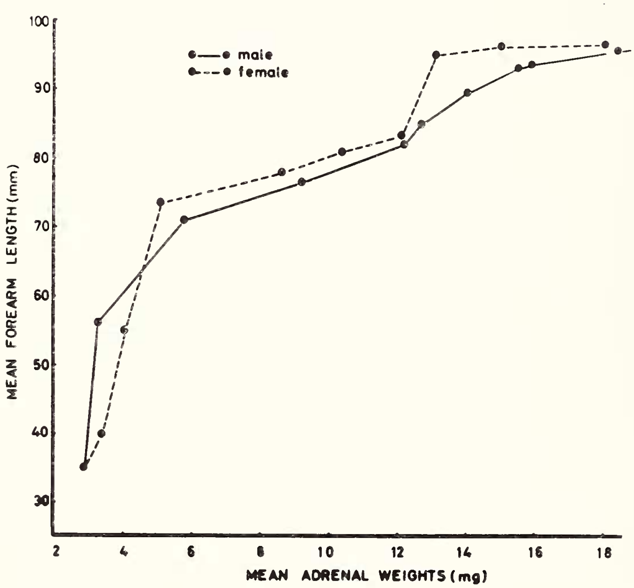


Fig. 2. The relationship between mean absolute adrenal weights and forearm length during the growth of juveniles

only slightly. The third and last phase which starts at around 12 mg adrenal weight marks a steady but short-lived growth after which the forearm length attains the adult size.

The adrenal weight continues to increase even after the bats have attained sexual maturity. The forearm length levels off while the adrenal weight increases at a steady rate. Like other organs such as kidneys and spleen, the increase in adrenal weights proceeds parallel with that of the body weight during the early stages of postnatal life. However, the attainment of adult body and adrenal weights takes place at different times.

Attainment of adult adrenal weights

The adrenal weights given in table 2, clearly show that there is a wide adrenal weight range. The highest adrenal weight figures for the immature bats, 18.6 mg for males and 17.9 mg for females, are higher than the lowest adrenal weight figures for non-breeders and breeders. This means that the adult adrenal weight is attained before the animals are mature enough to breed; or in other words that sexually immature bats have a great range of adrenal weights some of which have already reached adult adrenal weight levels.

By the fourth postnatal month, the adrenal weights of the young bats have stabilised somewhat in relation to age. At this age, the immature bats are fully independent of their mothers, and their mean adrenal weights are 10–12 mg for both sexes. This weight is within the adult adrenal weight range. In this study, the highest percentage of adrenal weights over body weights, 3%, is recorded in the youngest foetuses examined. The adrenals are generally 1.5 to 1.7% of the body weight for both the immature and mature bats. This indicates that in general weights increase proportionally throughout the postnatal life of the fruit bat (table 3).

Table 3

Adrenal weights and measurements of fourteen bats

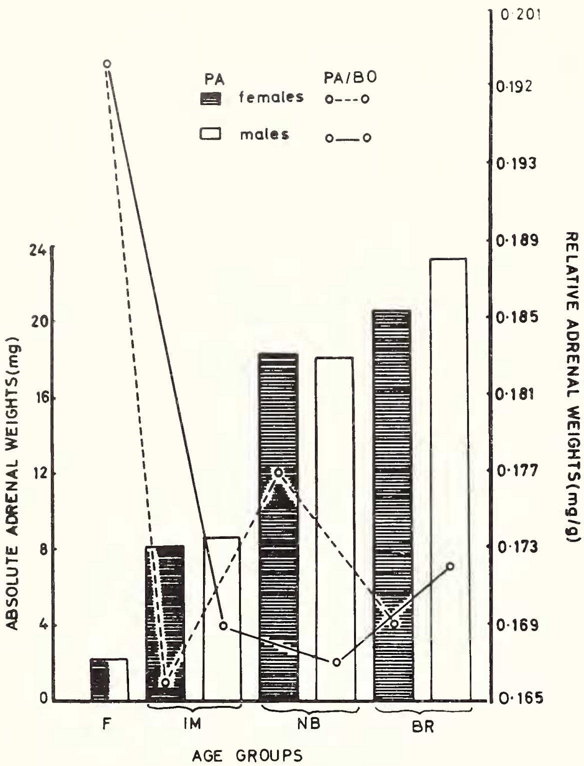
Specimen no.	Estimated age (months)	Body weight (g)	Forearm length (mm)	Right adrenal		Left adrenal		Absolute adrenal weight (mg)
				Weight (mg)	Length × width × thickness (mm)	Weight (mg)	Length × width × thickness (mm)	
577	*	10.4	34.6	0,7		0.7		1.4
609	0	17.9	35.6	1.1	1.7 × 1.2 × 1.1	1.1	1.7 × 1.3 × 0.9	2.2
540	1	38.2	72.0	3.8	2.3 × 2.0 × 1.9	3.8	2.4 × 2.0 × 1.8	7.6
522	2	51.6	77.3	3.8	2.7 × 1.8 × 1.2	3.8	2.9 × 2.0 × 1.4	7.6
525	3	63.1	77.7	4.2	2.5 × 2.0 × 1.6	4.6	2.8 × 2.0 × 1.8	8.8
554	4	70.0	86.0	12.0	2.8 × 2.5 × 1.9	6.6	3.0 × 2.5 × 2.0	18.6
658	5	71.1	81.7	5.2	2.6 × 2.3 × 1.9	5.7	3.0 × 2.2 × 1.6	10.9
507	6	88.8	92.0	4.1	2.5 × 2.0 × 1.7	4.5	2.8 × 1.9 × 1.7	8.6
664	7	93.4	99.0	7.5	3.3 × 2.5 × 1.9	8.6	3.6 × 2.2 × 1.9	16.1
588	8	102.0	91.1	8.3	3.8 × 2.8 × 1.9	9.3	3.9 × 2.8 × 2.1	17.6
686	9	108.3	100.3	8.8	3.1 × 2.6 × 2.0	9.4	3.5 × 2.5 × 2.1	18.2
680	10	117.4	92.0	7.4	3.1 × 2.5 × 2.0	7.4	3.5 × 2.6 × 2.1	14.8
670	H_1	134.5	97.8	7.8	3.4 × 2.5 × 1.8	9.0	3.4 × 2.5 × 2.3	16.8
672	H_2	155.2	96.0	9.8	3.2 × 2.7 × 2.2	11.7	3.3 × 2.7 × 2.3	21.5

Three linear measurements roughly at right angles to each other were made across the adrenal glands and recorded as length × width × thickness (mm). * This specimen was a roughly 2 months old foetus. Some of the measurements were not recorded. – H_1, H_2 = Age is unknown but is greater than ten months.

Adrenal weight changes from immature to breeding stages

A comparison of absolute and relative adrenal weights in various age groups during development and breeding was made. Considerable variation in the sample exists in the mean absolute and relative adrenal weights of foetuses, juvenile, non-breeding males and females (fig. 3). The mean absolute adrenal weights range from 2.3 mg in the foetuses to 23.2 mg in the breeding males. When the mean absolute adrenal weights are plotted against the mean body weights, the relationship between the two is expressed as a linear function.

The adrenal and body weights for growing bats are highly correlated ($r = 0.987$, $P < 0.001$) and the correlation remains high whether the figures used are means or individual, male or female (fig. 4). The high correlation figures for juvenile bats are lowered in mature



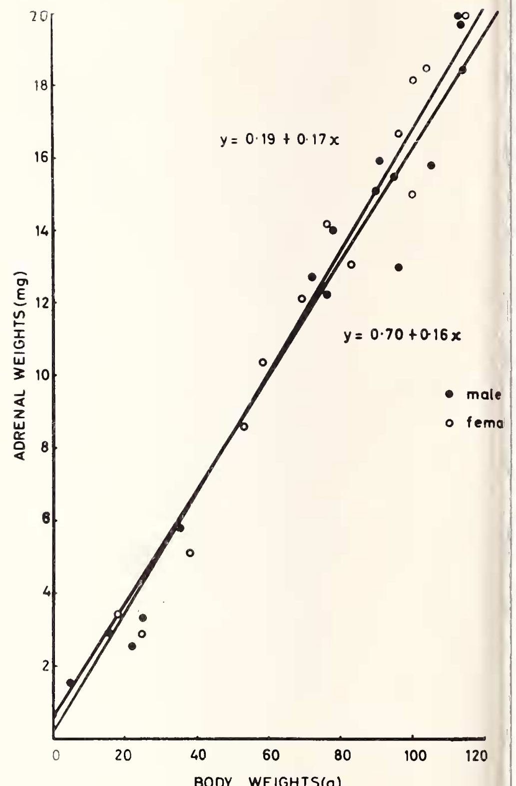


Fig. 3 (left). The changes of mean absolute and mean relative adrenal weights with the age groups. F = foetus; IM = immature; NB = nonbreeding; BR = breeding; PA = absolute adrenal weights; PA/BO = relative adrenal weights. – *Fig. 4 (right).* The relationship between absolute adrenal and body weights of juveniles

females (non-breeders: r = 0.472, $P<0.05$; breeders: r = 0.501, $P<0.10$) and lower still in males (r = 0.392).

A comparison of the two sexes reveals no significant differences in their absolute adrenal weights during development. In both sexes, significant differences are found in the mean absolute adrenal weights between the age groups: foetuses and juveniles ($P<0.001$), juveniles and non-breeders ($P<0.001$) while the difference between non-breeders and breeders is only significant in the males ($P<0.005$).

As fig. 3 shows, the mean relative adrenal weights of both sexes, decrease from foetal to juvenile stages and this is accentuated by the rapid increase in the body weight that is observed in juvenile bats. Thereafter, the mean relative adrenal weights follow different courses in the two sexes. The peak shown by the nulliparous females can be explained by their generally light bodies; a fact which changes as the bats start breeding, resulting in higher body weights and lower relative adrenal weights.

During the stages of development, the juvenile and non-breeding males have relatively heavy bodies and thus lower relative adrenal weights. The breeding male bats have the heaviest adrenals and therefore their mean relative adrenal weights reach a level higher than that of juvenile and non-breeding males.

Table 4

Mean monthly body weights (g) and weights of paired adrenal glands (mg) ± SE of male juveniles

Month of the year	Body weight (g) ± SE	Absolute adrenal weight (mg) ± SE	Relative adrenal weight (mg/g) ± SE	Sample size
1975				
March[1]	39.90 ± 5.466	6.975 ± 1.025	0.171 ± 0.001	16
April	31.61 ± 1.672	6.86 ± 0.345	0.210 ± 0.018	7
May	61.78 ± 3.328	11.45 ± 0.811	0.188 ± 0.013	13
June	72.36 ± 3.868	11.90 ± 0.789	0.168 ± 0.013	7
July	83.37 ± 3.000	8.17 ± 3.196	0.097 ± 0.037	3
August	83.00 ± 2.400	13.45 ± 1.650	0.162 ± 0.015	5
September	84.1 ± 1.270	14.15 ± 1.780	0.168 ± 0.019	4
October[1]	30.29 ± 3.877	3.53 ± 0.539	0.114 ± 0.005	16
November	41.49 ± 4.892	5.15 ± 0.449	0.128 ± 0.007	11
December	49.82 ± 1.582	7.42 ± 0.281	0.151 ± 0.006	18
1976				
January	70.00	18.6	0.266	1
February	67.17 ± 3.379	12.57 ± 1.620	0.190 ± 0.033	3

[1] Young bats are born early March and early October and this affects the juvenile mean weight records.

Table 5

Mean monthly body weights (g) and weights of paired adrenal glands (mg) ± SE of female juveniles

Month of the year	Body weight (g) ± SE	Absolute adrenal weight (mg) ± SE	Relative adrenal weight (mg/g) ± SE	Sample size
1975				
March	45.40 ± 1.860	7.414 ± 0.332	0.146 ± 0.010	7
April	45.60 ± 11.82 (4)	6.30 ± 1.045 (9)	0.165 ± 0.008 (4)	*
May	61.23 ± 5.24	10.47 ± 1.390	0.165 ± 0.012	6
June	73.63 ± 9.34	12.10 ± 2.930	0.163 ± 0.030	3
July	75.50 ± 2.352	11.50 ± 0.649	0.156 ± 0.011	6
August	79.15 ± 8.55	15.20 ± 1.200	0.196 ± 0.036	2
September	88.60	16.00	0.181	1
October	30.15 ± 5.99	4.86 ± 1.260	0.172 ± 0.045	10
November	38.26 ± 2.84	4.66 ± 0.440	0.122 ± 0.007	7
December	49.01 ± 1.67	8.23 ± 0.600	0.172 ± 0.016	10
1976				
January	61.20	12.10	0.198	1
February	62.84 ± 3.179	12.51 ± 1.112	0.181 ± 0.006	7

*Sample size is variable and is shown in parentheses.

Table 6

Mean monthly weights of paired adrenal glands of non-breeding males

Month of the year	Absolute adrenal weight (mg) ± SE	Relative adrenal weight (mg/g) ± SE	Sample size
1975			
March	17.83 ± 0.979	0.154 ± 0.010	20
April	18.15 ± 1.290	0.155 ± 0.019	4
May	15.75 ± 5.650	0.145 ± 0.450	2
June	18.19 ± 1.860	0.160 ± 0.013	7
July	18.10 ± 1.219	0.161 ± 0.010	9
August	20.37 ± 2.013	0.178 ± 0.013	7
September	17.89 ± 1.187	0.150 ± 0.011	8
October	17.45 ± 1.449	0.148 ± 0.012	8
November	16.90 ± 0.900	0.161 ± 0.013	2
December	–	–	
1976			
January	19.95 ± 1.343	0.175 ± 0.268	10
February	19.83 ± 0.940	0.168 ± 0.011	4

Table 7

Mean monthly weights of paired adrenal glands of non-breeding females

Month of the year	Absolute adrenal weight (mg) ± SE	Relative adrenal weight (mg/g) ± SE	Sample size
1975			
March	18.27 ± 0.667	0.161 ± 0.005	9
April	20.35 ± 0.050	0.200 ± 0.010	2
May	21.0	0.177	1
June	–	–	
July	14.4	0.155	1
August	17.67 ± 2.490	0.168 ± 0.017	3
September	20.05 ± 1.850	0.184 ± 0	2
October	–	–	
November	11.65 ± 0.250	0.117 ± 0.012	2
December	15.60	0.148	1
1976			
January	21.10 ± 1.600	0.211 ± 0.025	2
February	19.41 ± 1.095(8)	0.173 ± 0.009(4)	*

*Sample size is variable.

Seasonal changes in adrenal weights

Analyses of seasonal data on adrenal weights of bats of all ages are represented in tables 4 to 9. Two kinds of data are presented: first, actual total weights of paired adrenals referred to in the tables and elsewhere in the text as absolute adrenal weights. Secondly, adrenal weights relative to the body weight of the animal (mg paired adrenal weight per g body weight).

Table 8

Mean monthly weights of paired adrenal glands of breeding males

Month of the year	Absolute adrenal weight (mg) ± SE	Relative adrenal weight (mg/g) ± SE	Sample size
1975			
March	22.196 ± 0.633	0.156 ± 0.004	28
April	25.82 ± 1.584	0.186 ± 0.010	22
May	23.83 ± 1.583	0.179 ± 0.0007	18
June	25.81 ± 1.202	0.193 ± 0.010	17
July	23.71 ± 1.879	0.174 ± 0.119	10
August	22.27 ± 0.921	0.167 ± 0.009	14
September	22.77 ± 1.049	0.172 ± 0.007	18
October	23.40 ± 1.306	0.170 ± 0.010	8
November	18.84 ± 1.560	0.143 ± 0.011	11
December	–	–	11
1976			
January	24.78 ± 1.740	0.192 ± 0.013	11
February	26.96 ± 2.850	0.202 ± 0.016	7

Table 9

Mean monthly weights of paired adrenals of breeding females

Month of the year	Absolute adrenal weight (mg) ± SE	Relative adrenal weight (mg/g) ± SE	Sample size
1975			
March	24.91 ± 0.827	0.204 ± 0.006	39
April	26.53 ± 1.383	0.244 ± 0.119	18
May	20.99 ± 2.850	0.183 ± 0.028	7
June	20.73 ± 1.410	0.191 ± 0.013	9
July	21.01 ± 2.467	0.169 ± 0.183	9
August	22.12 ± 0.714	0.176 ± 0.005	27
September	23.66 ± 0.861	0.181 ± 0.005	22
October	19.81 ± 1.202	0.164 ± 0.008	29
November	20.16 ± 1.374	0.170 ± 0.010	19
December	21.62 ± 2.460	0.177 ± 0.019	4
1976			
January	22.78 ± 1.109	0.182 ± 0.007	17
February	25.68 ± 0.930	0.190 ± 0.006	17

Changes in adrenal weights of the bats are very closely related to changes in body weights in both sexes throughout the sampling year. Therefore, the relative adrenal weight changes follow closely the trend of the absolute adrenal weight changes, and if differences occur, they are not significant.

Changes with reproductive periods

The mean absolute adrenal weights increase gradually with the mean body weights from early pregnancy and both reach a peak during late pregnancy. This increase is found to be significant ($P < 0.01$) although the change of mean relative adrenal weights over the same period is not. From the late pregnancy peak, both the mean absolute and mean relative adrenal weights decrease and have low averages during lactation (fig. 5).

The low mean figures of both absolute and relative adrenal weights do not change significantly during lactation. Although the gravimetric data of postpartum females may appear to be higher than those of similar animals during early pregnancy, the differences are statistically insignificant. The mean relative adrenal weights throughout the reproductive period, are characteristically high during early pregnancy and lower otherwise.

The early pregnancy peak decreases with the progress of pregnancy until it hits the bottom during mid-pregnancy (fig. 6). It recovers slightly during late pregnancy only to go down slightly after parturition where it remains until the next pregnancy. The differences in the relative adrenal weights of female bats from early pregnancy up to weaning are very small and statistically insignificant.

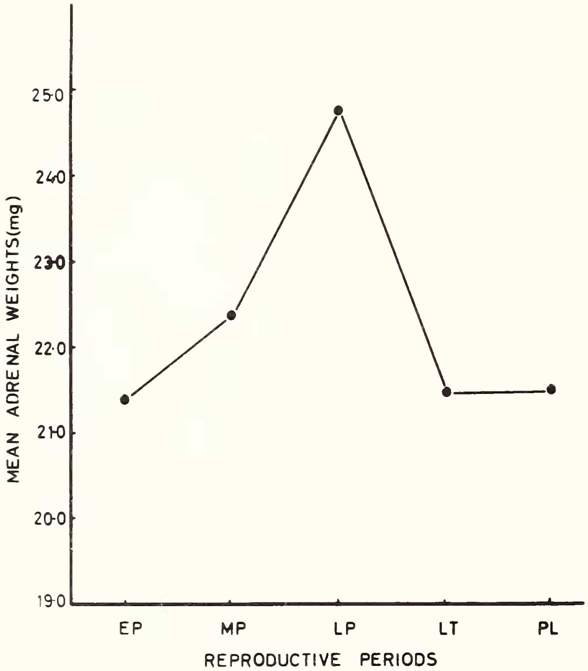


Fig. 5. Absolute adrenal weight changes with the reproductive periods: EP = early pregnancy; MP = mid-pregnancy; LP = late pregnancy; LT & PL = lactation

Seasons

Attempts have been made to correlate adrenal gland size with other parameters and characteristics that are suspected to have a bearing on the adaptation of the bats to their environment such as wet and dry seasons.

The rainfall data collected (fig. 7) and the observations made during the present work confirm earlier observations (Mutere 1968) that the bimodal breeding pattern of *R. aegyptiacus* under study, follows closely the two tropical rainfall peaks. This makes it very difficult to find out whether the observed variations in the adrenal weights are due to seasonality or to breeding conditions.

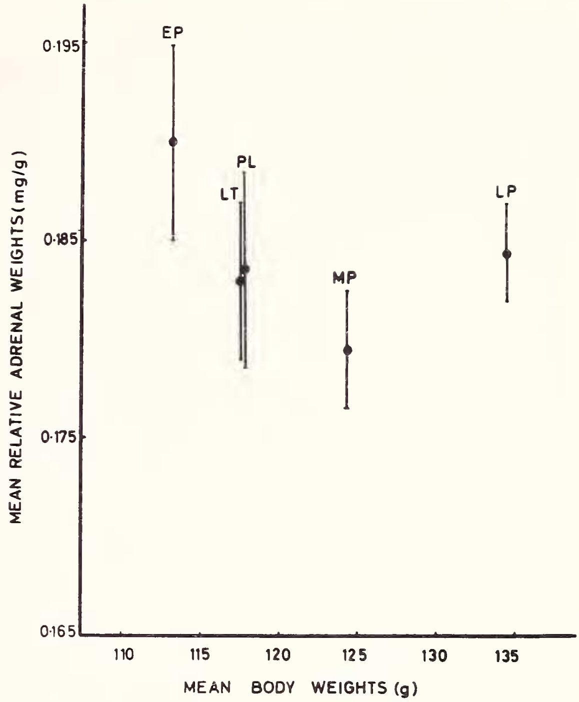


Fig. 6. Relative adrenal weight changes with the reproductive periods. (Legend as in Fig. 5)

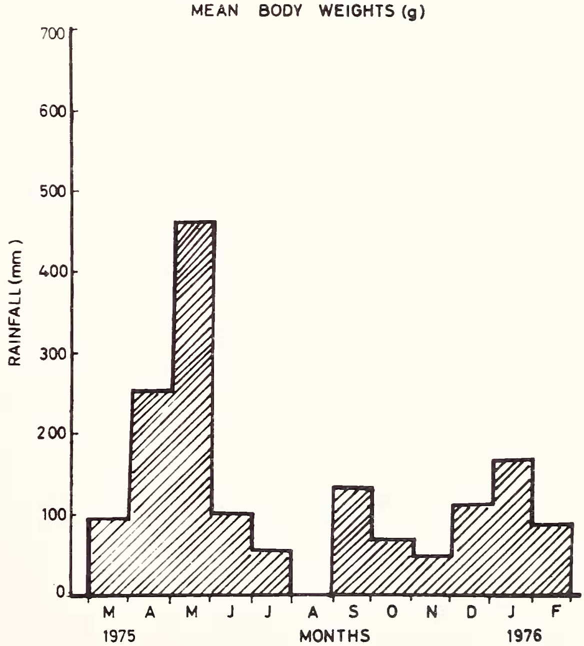


Fig. 7. Monthly rainfall for the area collected during the period of study

Seasonality is not considered significant in its effects on adrenal weights in the tropics except in as far as it affects the availability of food. The bats have access to abundant supplies of natural food plants from the lake-shore forest as well as some cultivated crops and thus the food resources cannot possibly constitute a limiting factor. It appears therefore that there is no measureable relationship found to link adrenal size with any of these features.

Discussion

Right and left adrenals

Disproportionate weight favouring one adrenal has been reported before, in rodents (Donaldson 1924; Kojima 1928, Jones 1957; Rudd and Mullen 1963; Mullen 1960; Pinter 1968), rabbits (Bailey and Schroeder 1967), echidna (Weiss and Mcdonald 1965) dog (Baker 1937), cattle (O'Kelly 1974), Tasmanian devil (Weiss and Richards 1971) and bats (Christian 1956; Short 1961; Rudd and Beck 1969). Although the percentage difference is lower in *R. aegyptiacus* than the 20% reported in rodents (Rudd and Mullen 1963), the left gland is heavier than the right one in both cases.

In contrast to the present findings on fruitbats, Baker (1937) working on dogs found that, the right adrenal was heavier than the left one. Jones (1957) attributed no functional significance to the difference between left and right adrenals, but he only speculated about its relationship with the adrenal's anatomical closeness to the neighbouring kidney. The closeness of the right and left bat adrenals to their corresponding kidneys in the present work, is similar and thus does not account for the persistent differences observed.

Christian (1956) found a disproportionately heavier right adrenal in *Eptesicus* bats and similar results were obtained a few years later in *Tadarida* bats by Short (1961). The increased total adrenal weight during late pregnancy in the two bat species is attributed to the differential increase in the right adrenal weight. The information obtained by Rudd and Beck (1969) on pregnant *Myotis yumanensis* females agreed with the findings of Christian (1956) and Short (1961); and they apparently correlated the differential adrenal weight increase with the consistent use of the right uterine horn in pregnancy.

The information obtained in the course of the present investigation, shows a 50% chance of implantation in either of the two uterine horns. This shows that no particular horn is persistently favoured in *R. aegyptiacus* as was the case in *M. yumanensis* (Rudd and Beck 1969). As reported earlier on, there is a dramatic increase in adrenal weights from sexually inactive to breeding females especially during late pregnancy. It is clear that the differential increase of the left adrenal especially during late pregnancy is the major contributor to the total adrenal increase of breeding females. This conclusion agrees with that of other workers (Rudd and Beck 1969) although neither left nor right uterine horn is persistently favoured in *R. aegyptiacus* pregnancies.

Adrenal weight changes with sex

Sex, age and breeding are among some of the factors which may affect weight changes in adrenal glands. In fact, most mammals show considerable adrenal weight variations among individuals of the same species, sex, size and age. The female mouse has heavier total adrenals than those of the coeval male (Jones 1948; 1955) and similar results were reported in the rat (Hatai 1914; Donaldson 1924; Jones 1957; Barnett et al. 1974).

The present work on *R. aegyptiacus* shows that among the juveniles, the male adrenal glands are heavier than the female ones. Among the non-breeding bats of both sexes, the mean adrenal weights are almost equal, while the breeding males have a greater mean adrenal weight than their female counterparts. This is at variance with what other workers found in the mouse (Jones 1957), in the rat (Donaldson 1924; Barnett et al. 1974) and in elephants (Krumrey and Buss 1969); but is in agreement with the findings on *Myocastor coypus* (Wilson and Dewees 1962), golden hamster (Peczenik 1944; Meyers and Charriper 1956), rabbit (Christian 1953; McKinney et al. 1970) and man (Bachman 1954; Symington 1961).

The average figures (tab. 2) given in the present work, mask the higher adrenal weights of late-term pregnant females which are generally greater than those of the coeval breeding males. Similar results were obtained by Christian (1956) working on *Eptesicus fuscus*. Although the sex difference in the adrenal weights are not striking in *R. aegyptiacus* as in the golden hamster (Jones 1957), results from the two animals agree in that, on the average, the adrenal weights are higher in old males than in females of the same age.

Other workers have found similar results which confirm that contrary to the general belief (Krumrey and Buss 1969), in some mammals adrenals of males are heavier than those of females (Jones 1957; Wilson and Dewees 1962). And yet in other mammals, little sex differences have been reported for instance in the dogs (Baker 1937; 1938) and guinea-pigs (Jones 1957).

Growth of adrenals

The absolute adrenal weights of bat foetuses are the lowest in the whole sample. This differs from the case of the human adrenal which is much larger in the foetus than in the neonate (Eckholm and Niemineva 1950; Stoner et al. 1953; Symington 1969). The proportionate growth of absolute adrenals to the general body growth in young bats contrasts highly with the relative adrenal weights for the same animals. The relative adrenal weights are highest in the prenatal bats and drop to a minimum at about the period of birth. In comparison to the body weight, the foetal adrenal is heavy as evident from the high prenatal relative adrenal weights. These observations are similar to the findings on human relative adrenal weight which is highest in prenatal specimens (Eckholm and Niemineva 1950; Symington 1969).

The continuous increase in the absolute adrenal weights of bats, from prenatal to postnatal stages, shows that the immediate pronounced adrenal involution which follows birth in man, does not happen in *R. aegyptiacus*. This is strongly supported by histological evidence from the adrenals at those stages. Thus the decrease in relative adrenal weights of neonatal bats may be due to disproportionate growth in favour of the body weight immediately after birth. In proportion to body weight, the *Rousettus* adrenal is smaller than many other mammalian adrenals.

Seasonal variation in adrenal weights

Considerable changes are known to occur in adrenal glands of mammals inhabiting areas of marked climatic fluctuations (Christian 1962; Goertz 1965; Rudd and Beck 1969; Chan and Phillips 1973). It is also true that where seasonal variations exist, mammals usually exhibit definite breeding periods. While the climatic conditions vary but little in tropical regions like Uganda, the rainfall pattern shows two distinct peaks.

Climate and breeding usually present problems in interpretation of adrenal data, but the definite bimodal breeding pattern of *R. aegyptiacus* in Uganda (Mutere 1968) which is closely followed by the rainfall peaks, complicates the picture further. Much of the work on the adrenal weights has been done in the temperate areas and there is a paucity of work done in the tropics for comparisons. Therefore, it has not been easy to attribute the adrenal weight changes to rainfall (in as much as it affects food availability) or to breeding.

Juveniles

With a few exceptions, where monthly samples are small, the mean monthly absolute adrenal weights of juvenile bats show a steady increase from one parturition peak in March to the next in September/October. Following the recruitment of very young bats in the sample during the birth peaks, the mean absolute adrenal weights of juveniles decline. This indicates that the adrenal weights of juvenile bats do not respond to any particular seasonal factors except in as much as the latter means parturition and therefore the inclusion of many small adrenals in the sample.

Non-breeders

The nulliparous females and the non-breeding males show three adrenal weight peaks and two main low averages in the year. Superficially it looks as if the adrenal weight peaks are correlated to the mean annual rainfall peaks. It may be attractive to advance a hypothesis about the relationship of food availability – and the related responsiveness of the adrenal-to rainfall. It is not possible, however, to elaborate on this without first studying the food habits of the animal over the same period of time. Moreover, much of the conclusions on the non-breeding *Rousettus* bats will remain speculative since the monthly sample for this age group was not always big enough to guarantee accurate deductions.

Breeders

Information is available that oestrogen levels in human females increase as the pregnancy advances until a peak is reached during late pregnancy after which they decline at birth (Roy and Mackay 1962; Coyle and Brown 1963). Like oestrogen during human pregnancy, the bat adrenal weights increase with the advance of pregnancy and decline suddenly at parturition. The coincidence of the adrenal weight increase with the behaviour of oestrogen during bat pregnancy increases the probability that the latter stimulates the former. This is in agreement with the findings of other workers on the stimulatory effect of oestrogen on adrenal function (Miller and Riddle 1939; Conner and Shaffner 1954; Zalesky 1934; Clough 1965).

Generally the adrenal weights of breeding males are high during the breeding period. Low adrenal weight averages are recorded for male breeders during the female lactation period starting with parturition. The male adrenal weights increase during the female postlactation and throughout the four months of gestation. It is known that maximum male testicular weight occurs around the time of, and soon after the female parturition (Mutere 1968),and this may reflect a peak for testosterone secretion in the male bats. It is probable then that the low male bat adrenal weights following parturition is in response to the androgens which may reach a peak at that time.

Similar results have been obtained in both mammals and birds to confirm the effect of androgens on the adrenals (Kar 1947; Roy and Mahesh 1964; Chan and Phillips 1973). The increase in the mean adrenal weights of male bats starting immediately after lactation until the late pregnancy periods of their coevals, can be attributed to the decreasing effect of androgens, increased male aggressiveness which is evident during the breeding periods, and increased social contact as a result of reproductive recruitment of young bats into the population.

Increase in adrenal weights has been recorded in *Eutamias* (Sheppard 1968) and woodchucks (Christian 1962) at postlactation, by which time the young are dispersing. Breeding periods in the Ugandan *Rousettus aegyptiacus* are so close to each other that it is not easy to distinguish between the effects of breeding on adrenal response from those of other factors such as wet and dry seasons, food scarcity and its consequent stressful foraging trips, social contact and its concomitant heightened scuffles.

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